

Positional effects on femoral vein cross-sectional area: a prospective ultrasonographic study

 İhsaniye Süer Doğan¹,  Nezir Kavak²

¹Department of Radiology, Ankara Etlik City Hospital, Ankara, Türkiye

²Department of Emergency Medicine, Ankara Etlik City Hospital, Ankara, Türkiye

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ABSTRACT

Aims: The study aimed to assess the variation in femoral vein diameter and cross-sectional area (CSA) across different body positions in a cohort of healthy Turkish adults and to explore the associations between venous measurements and demographic variables, including age, sex, and body-mass index (BMI).

Methods: Ultrasonographic measurements of the right and left femoral vein diameters and CSA were obtained in five distinct body positions from 278 healthy adults, encompassing a total of 556 lower limbs. Demographic parameters, including age, sex, and BMI, were systematically documented for each participant.

Results: A total of 278 participants (556 limbs) were analysed. Males exhibited significantly higher femoral vein CSA than females across all positions ($p < 0.001$). The lowest mean CSA was in the Trendelenburg position ($0.87 \pm 0.08 \text{ cm}^2$), and the highest in the reverse Trendelenburg+frog-leg position ($1.51 \pm 0.11 \text{ cm}^2$) ($p < 0.001$). CSA positively correlated with age in all positions except Trendelenburg ($r = 0.400 - 0.479$, $p < 0.001$). Overweight and obese (class I) individuals showed significantly higher CSA values than normal or underweight participants ($p < 0.001$).

Conclusion: This study demonstrates that body positioning significantly affects the CSA of the femoral vein. Additionally, factors such as age, sex, and BMI were found to significantly influence femoral vein calibre.

Keywords: Femoral vein, cross-sectional area, ultrasonography

INTRODUCTION

Central venous catheterisation (CVC) is a routine clinical procedure involving the insertion of a catheter into major central veins, typically the internal jugular, subclavian, or femoral veins, with the catheter tip advanced towards the superior or inferior vena cava, or directly into the right atrium.¹ This intervention is a cornerstone in the management of critically ill patients, particularly within emergency and intensive care settings.² In individuals with end-stage renal disease, CVCs remain an essential modality for initiating or maintaining haemodialysis, particularly in cases where arteriovenous fistula or graft placement is not feasible or when peripheral venous access is inadequate.³ Furthermore, the administration of venotoxic drugs or vasopressors is particularly necessary for certain pharmacological agents, such as vasopressors and other vesicant or irritant drugs, due to the high risk of extravasation and tissue necrosis associated with peripheral infusion routes.⁴

Central venous lines also assist the reliable delivery of parenteral nutrition in patients unable to tolerate or benefit from enteral feeding.⁵ In addition, they are essential

components in extracorporeal therapies, including continuous renal replacement therapy and plasmapheresis.⁶

Among central access sites, the femoral vein is frequently preferred for its large caliber, relatively straightforward anatomical approach, ease of cannulation, and reduced procedural time.^{2,7}

Particularly, the femoral vein's extrathoracic course eliminates the risk of iatrogenic pneumothorax, an important advantage over subclavian or internal jugular catheterisation, as supported by recent evidence demonstrating a threefold lower incidence of such mechanical complications at the femoral site.^{8,9}

The femoral vein's extrathoracic anatomical location allows CVC to be performed without interrupting chest compressions during cardiopulmonary resuscitation, a significant advantage in emergent settings, while also offering rapid access and low complication rates.^{10,11}

Ultrasonography (USG) is a widely used imaging technique that offers real-time visualization of blood vessels without the need for radiation or invasive procedures. Its portability

Corresponding Author: İhsaniye Süer Doğan, dr.ihsaniye@gmail.com



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allows for quick application at the patient's bedside, where it provides valuable guidance during interventions by allowing simultaneous visualization of both the needle tip and surrounding vascular anatomy.

The utilisation of USG to guide central venous access has been shown to improve procedural success rates while significantly reducing the incidence of mechanical complications.¹² Ultrasound-guided improves the efficiency, safety, and comfort during CVC.⁴

Ultrasound-guided catheterisation has become an increasingly advocated standard of care in recent clinical guidelines, as it has been widely adopted for its proven benefits in enhancing procedural safety and success rates.¹³

The cross-sectional area (CSA) of a blood vessel is defined as the two-dimensional area observed in a transverse (short-axis) ultrasound view. It reflects the actual size of the vessel lumen and is commonly determined by manually tracing the inner border of the vessel under real-time ultrasound guidance. Compared to diameter measurements alone, CSA offers a more reliable estimation, particularly in vessels that are non-circular in shape or prone to compression.

An enlarged CSA of the femoral vein has been associated with a higher likelihood of successful catheter insertion on the first attempt. Conversely, catheterisation performed when the vein is constricted may increase the risk of adverse outcomes, including retroperitoneal haemorrhage, peritoneal catheter misplacement, and perivascular haematoma. These complications can be mitigated by selecting an anatomical site where the vein exhibits maximal CSA.¹⁴

Previous studies have shown that the CSA of the femoral vein is modulated by several intrinsic and extrinsic factors, including demographic attributes (e.g., age and sex), anthropometric variables such as body-mass index (BMI), and body positioning.¹⁵⁻¹⁷

Incorporating these considerations into clinical decision-making during femoral vein catheterisation may improve procedural efficacy and minimise complications.

The present study aims to characterise how femoral vein diameter and CSA in healthy Turkish adults are influenced by different body positions and to analyse the associations of these measurements with demographic variables such as age, sex, and BMI.

METHODS

Ethics

This single-center, prospective observational study on volunteers was conducted between May 1-15, 2025 after approval by the Scientific Researches Evaluation and Ethics Committee of Ankara Etlik City Hospital No. 1. (Date: 30.04.2025, Decision No: 2025/157). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants after a detailed explanation of the study objectives and methodology.

Study Population

The study enrolled healthy adult volunteers aged 18 years and above. Exclusion criteria included unwillingness to participate, suspected or known abdominal or pelvic pathology, chronic systemic conditions with potential vascular involvement, structural abnormalities of the femoral vessels, prior surgical intervention in the femoral region, and any condition that prevented the participant from assuming the required body positions (e.g., physical disability).

Study Protocol and Measurements

The age (in years), height (in centimeters), and weight (in kilograms) of each volunteer were recorded. BMI was subsequently calculated using the standard formula: $BMI = \text{weight (kg)} / \text{height}^2 (\text{m}^2)$. Participants were categorized into four BMI groups according to the guidelines established by the Centers for Disease Control and Prevention and the National Institutes of Health, under the United States Department of Health and Human Services. Individuals with a BMI of less than 18.5 kg/m² were categorized as underweight. Those with a BMI between 18.5 and 24.9 kg/m² were considered to have normal weight. Participants with a BMI ranging from 25.0 to 29.9 kg/m² were classified as overweight, while individuals with a BMI between 30.0 and 34.9 kg/m² were categorized as obese, specifically class I obesity.¹⁸

Demographic and anthropometric data, including age (years), BMI, were collected for each participant.

Ultrasonography Examinations

All ultrasonographic assessments were conducted using a LOGIQ E10 ultrasound system (GE HealthCare), equipped with a high-frequency linear array transducer operating within the 4.0–20.0 MHz range. A single radiologist with 25 years of clinical experience in diagnostic imaging performed all measurements to ensure consistency and reduce operator variability.

The five body positions examined in this study were selected based on prior evidence demonstrating their influence on right and left femoral vein morphology:

Supine position: Regarded as the standard anatomical posture and used as the reference point for all comparative measurements.

Trendelenburg position: Participants were positioned with the head of the bed lowered and the lower extremities elevated at an angle of approximately 10–15 degrees.

Reverse Trendelenburg position: The upper body was elevated while the legs were lowered, creating a head-up tilt of approximately 10–15 degrees.

Frog-leg position: Participants flexed their knees and abducted their hips such that the soles of the feet were in contact near the midline. This position combines hip abduction, external rotation, and knee flexion.

Reverse Trendelenburg+frog-leg combination: Participants were placed in the reverse Trendelenburg orientation while concurrently assuming the frog-leg posture.

USG measurements were obtained using a linear transducer positioned transversely, 1 cm inferior to the inguinal crease, a site routinely recommended for percutaneous femoral vein catheterisation. Vein diameters were measured from intima to intima in both longitudinal and transverse planes. The CSA of the femoral vein was measured using manual contour tracing followed by automated planimetric analysis. In each of the five predetermined body positions, the diameter and CSA of both the right and left femoral veins were recorded and expressed in square centimetres (cm²). The mean femoral vein CSA was calculated by averaging the CSA values of the right and left femoral veins for each participant (**Figure a, b, c, d, e**).

Statistical Analysis

Continuous variables were summarised using descriptive statistics, including mean, standard deviation, median, and minimum–maximum values. Categorical variables were reported as frequencies and percentages. Comparisons between right and left femoral vein measurements were performed using the paired samples t-test. Differences in vein diameter and CSA between male and female participants were evaluated using the independent samples t-test. One-way analysis of variance (ANOVA) was applied to assess differences across BMI categories, while repeated measures ANOVA was used to examine changes in venous measurements across the five body positions. The relationship between age and femoral vein CSA was analysed using Pearson's correlation coefficient. Where significant differences were observed among BMI subgroups, post-hoc analysis was performed using the Tukey test. All statistical analyses were conducted using IBM SPSS Statistics, version 20.0 (IBM Corp., Armonk, NY, USA), with a p-value <0.05 considered indicative of statistical significance.

RESULT

A total of 278 participants, representing 556 lower limbs, volunteered for the study. The mean age of the study population was 44.84±16.28 years, with an age range of 18 to 65 years (**Table 1**). No statistically significant differences were observed between the right and left femoral vein CSA measurements across any of the examined body positions (p>0.05) (**Table 2**).

In all five body positions (supine, Trendelenburg, reverse Trendelenburg, frog-leg, and the combined reverse Trendelenburg with frog-leg), the mean femoral vein CSA values were significantly lower in female participants compared to males (p<0.001 for all comparisons) (**Table 3**).

Table 1. Demographic and anthropometric characteristics of the participants

(n=278)	Mean±SD median (min-max)	
Age (year)	44.84±16.28 47 (18-65)	
Body-mass index (kg/m ²)	26.41±3.69 24.2 (18-31.4)	
	n	%
Gender		
Female	133	47.8
Male	145	52.2
Body-mass index group		
Underweight	2	0.7
Normal	140	50.4
Overweight	40	14.4
Obese (class I)	96	34.5

SD: Standard deviation, Min: Minimum, Max: Maximum

Table 2. Comparison of right and left femoral vein cross-sectional area measurements of the participants

	Mean±SD median (min-max) (cm ²)	Mean±SD median (min-max) (cm ²)	p value
Supine position CSA	1.26±0.26 1.18 (0.93-1.99)	1.29±0.56 1.18 (0.92-9.60)	0.378 ^b
Trendelenburg position CSA	0.87±0.08 0.87 (0.70-1.19)	0.88±0.08 0.87 (0.70-1.19)	0.600 ^b
Reverse Trendelenburg position CSA	1.26±0.11 1.24 (1.0-1.98)	1.26±0.11 1.24 (1.0-1.98)	0.600 ^b
Frog leg position CSA	1.40±0.12 1.39 (1.20-1.62)	1.40±0.12 1.39 (1.2-1.69)	0.447 ^b
Reverse Trendelenburg+ frog-leg position CSA	1.51±0.11 1.50 (1.30-1.79)	1.51±0.11 1.50 (1.30-1.78)	0.439 ^b

SD: Standard deviation, Min: Minimum, Max: Maximum, CSA: Cross-sectional area, b: Paired samples t-test

The Trendelenburg position yielded the lowest mean femoral vein CSA, with values significantly reduced compared to all other positions (p<0.001). Although the supine position demonstrated higher CSA values than the Trendelenburg position, it resulted in lower CSA measurements than those recorded in both the frog-leg and reverse Trendelenburg+frog-leg positions (p<0.001 for all comparisons).

The reverse Trendelenburg+frog-leg position showed the highest mean femoral vein CSA values, which were significantly greater than those observed in all other positions (p<0.001 for all) (**Table 4**).

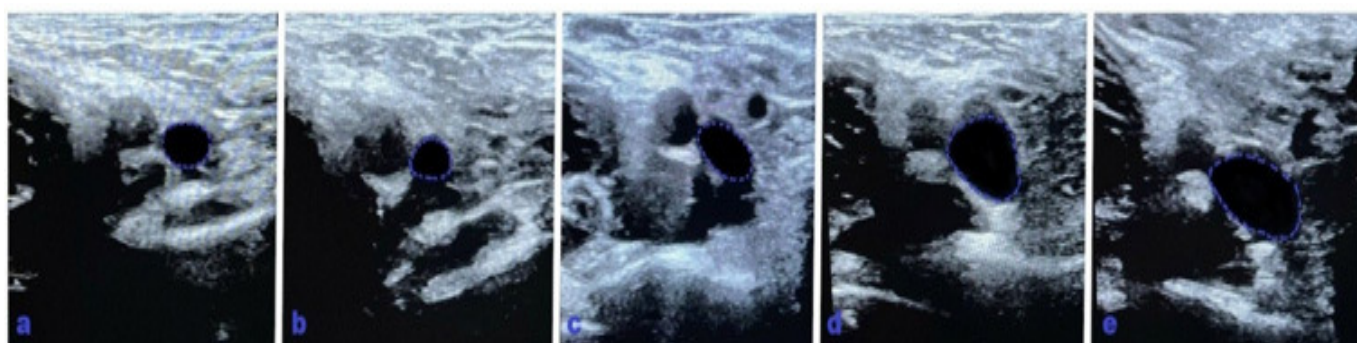


Figure a, b, c, d, e. Ultrasonographic scans showing femoral vein cross-sectional area measurements of volunteers in five different body positions: supine (a), Trendelenburg (b), reverse Trendelenburg (c), frog leg (d), reverse Trendelenburg+frog-leg position (e).

Table 3. Comparison of femoral vein cross-sectional area measurements between female and male participants

	Female	Male	P
	Mean±SD median (min-max) (cm ²)	Mean±SD median (min-max) (cm ²)	
Supine position CSA	1.30±0.50 1.15 (0.93-5.27)	1.25±0.09 1.27 (1.10-1.57)	<0.001 ^d
Trendelenburg position CSA	0.83±0.05 0.84 (0.70-0.95)	0.91±0.09 0.90 (0.83-1.19)	<0.001 ^d
Reverse Trendelenburg position CSA	1.22±0.12 1.19 (1.0-1.98)	1.31±0.08 1.29 (1.20-1.57)	<0.001 ^d
Frog-Leg position CSA	1.30±0.06 1.32 (1.20-1.40)	1.49±0.08 1.50 (1.35-1.65)	<0.001 ^d
Reverse Trendelenburg+frog leg position CSA	1.41±0.06 1.39 (1.30-1.59)	1.60±0.07 1.60 (1.41-1.79)	<0.001 ^d

SD: Standard deviation, Min: Minimum, Max: Maximum, CSA: Cross-sectional area, d: Independent samples t-test

Table 4. Comparison of femoral vein mean cross-sectional area measurements across different body positions of the participants

	Mean±SD (cm ²)	Median (min-max) (cm ²)	P
Supine position CSA	1.27±0.35	1.18 (0.93-5.27)	<0.001 ^g
Trendelenburg position CSA	0.87±0.08	0.87 (0.70-1.19)	
Reverse Trendelenburg position CSA	1.26±0.11	1.24 (1.0-1.98)	
Frog leg position CSA	1.40±0.12	1.39 (1.20-1.65)	
Reverse Trendelenburg+frog leg position CSA	1.51±0.11	1.50 (1.30-1.79)	

SD: Standard deviation, Min: Minimum, Max: Maximum, CSA: Cross-sectional area, g: Repeated measures analysis of variance (repeated measures ANOVA)

Across all positional measurements, a moderate positive correlation was identified between age and the mean CSA of the femoral vein (**Table 5**).

Table 5. Comparison of femoral vein mean cross-sectional area measurements according to participants' age and body positions

	Age	
	r*	P
Supine position CSA	0.400	<0.001
Trendelenburg position CSA	0.013	<0.001
Reverse Trendelenburg position CSA	0.468	<0.001
Frog leg position CSA	0.479	<0.001
Reverse Trendelenburg+frog-leg position CSA	0.428	<0.001

* Pearson correlation coefficient, CSA: Cross-sectional area

In the supine position, participants classified as obese (class I) exhibited significantly greater femoral vein CSA values than those in the underweight/normal-weight and overweight categories ($p<0.001$ for all comparisons).

In the Trendelenburg position, CSA values were significantly lower among obese (class I) individuals compared to both underweight/normal-weight and overweight participants ($p<0.001$ for all), indicating a positional influence on venous distensibility specific to BMI category.

In the reverse Trendelenburg position, both overweight and obese (class I) participants demonstrated significantly elevated CSA values relative to individuals in the underweight/normal-weight group ($p<0.001$).

During the frog-leg positioning, the highest femoral vein CSA values were observed in the overweight group, whereas the lowest were recorded among underweight/normal-weight individuals. Statistically significant differences were found across all BMI subgroups in this position ($p<0.001$ for all comparisons).

Finally, in the combined reverse Trendelenburg+frog-leg position, both overweight and obese (class I) individuals displayed significantly greater CSA values than those in the underweight/normal-weight category ($p<0.001$), underscoring the cumulative effect of body position and anthropometric status on femoral vein calibre (**Table 6**).

DISCUSSION

The femoral vein continues to serve as a critical anatomical site for central venous access, particularly in emergent clinical scenarios where rapid, dependable vascular access is paramount. Its anatomical accessibility, especially during ongoing cardiopulmonary interventions, renders it a preferred route under time-sensitive conditions.

Recent advances in ultrasound-guided techniques, infection control strategies, and catheter materials have made femoral venous access a safe and effective alternative to other central venous catheterization routes, even outside dialysis settings.¹⁰

However, most of the existing literature on femoral vein morphometry has been derived from populations with differing ethnic and physiological profiles.¹⁹ Consequently, previously established normative data may have limited applicability to the Turkish population due to potential interethnic anatomical variability. This underscores the necessity for population-specific vascular reference data to enhance the precision and safety of clinical interventions.

The present study addresses this gap by establishing normative values for femoral vein CSA in a healthy Turkish cohort and by systematically evaluating the influence of body positioning and individual demographic variables, namely sex, age, and BMI, on venous calibre. By delineating how these variables modulate femoral vein CSA across multiple clinically relevant postures, the findings offer a more tailored framework for optimising CVC strategies in Turkish adults.

Specifically, the mean femoral vein CSA observed in the supine position was 1.27 ± 0.35 mm², aligning closely with values previously reported in international studies involving adult populations.¹⁵

The lowest mean femoral vein CSA was recorded in the Trendelenburg position (0.87 ± 0.08 cm²), reflecting a notable constriction of the venous lumen in this orientation. This observation suggests that the Trendelenburg position may not be optimal for femoral venous access, as the gravitational gradient likely enhances venous return from the lower extremities, thereby reducing venous distension and intraluminal volume. Comparable findings were reported by

Table 6. Comparison of femoral vein mean cross-sectional area measurements according to participants' body-mass index

	18.5-24.9 (Underweight+normal)	25-29.9 (Overweight)	30-34.9 (Obese (class I))	P
	Mean±SD median (min-max) (cm ²)	Mean±SD median (min-max) (cm ²)	Mean±SD median (min-max) (cm ²)	
Supine position CSA	1.16±0.37 1.14 (0.93-5.27)	1.27±0.03 1.28 (1.18-1.44)	1.43±0.32 1.27 (1.10-1.99)	<0.001 ^f
Trendelenburg position CSA	0.90±0.10 0.88 (0.79-1.19)	0.88±0.03 0.90 (0.83-0.93)	0.83±0.06 0.83 (0.70-0.93)	<0.001 ^f
Reverse Trendelenburg position CSA	1.22±0.10 1.21 (1.0-1.97)	1.33±0.08 1.33 (1.20-1.57)	1.29±0.13 1.27 (1.19-1.98)	<0.001 ^f
Frog leg position CSA	1.36±0.10 1.38 (1.20-1.65)	1.54±0.05 1.55 (1.40-1.62)	1.41±0.11 1.39 (1.21-1.62)	<0.001 ^f
Reverse Trendelenburg+frog leg position CSA	1.47±0.10 1.50 (1.30-1.69)	1.62±0.04 1.62 (1.55-1.71)	1.51±0.12 1.50 (1.32-1.79)	<0.001 ^f

SD: Standard deviation, Min: Minimum, Max: Maximum, CSA: Cross-sectional area, f: One-way analysis of variance (ANOVA)

Kim et al.,¹⁷ who demonstrated that a 15-degree Trendelenburg tilt resulted in an approximate 32% reduction in femoral vein CSA, a change that reached statistical significance. This haemodynamic response is plausibly attributed to the cephalad shift of venous blood under gravitational influence, diminishing venous pooling within the femoral segment.

Conversely, positioning participants in the reverse Trendelenburg orientation led to a substantial augmentation in femoral vein CSA, with a mean value of 1.26 ± 0.11 cm², representing a marked increase relative to the supine baseline. These findings align with those of Stone et al.,¹⁵ who observed a significant CSA enhancement in the reverse Trendelenburg position in a cohort of 52 adults, with no significant lateral asymmetry between the right and left femoral veins. A plausible physiological mechanism underlying the observed CSA enlargement in the reverse Trendelenburg position involves a redistribution of hydrostatic forces due to elevation of the upper body relative to the lower extremities. This postural adjustment promotes venous pooling in the lower limbs, and the resultant elevation of the right atrium above the level of the femoral vein augments the pressure gradient along the venous axis. The reduced gravitational drainage toward the thoracic cavity and increased peripheral venous pressure may collectively elevate intraluminal tension within the femoral vein, thereby contributing to the observed increase in CSA.¹⁶

An even more pronounced distension of the femoral vein was noted in the frog-leg position, where the mean CSA reached 1.40 ± 0.12 cm² in the present study. These results are in partial agreement with the findings of Czyżewska et al.,¹⁴ who reported a mean femoral vein CSA of 114 ± 35 mm² measured at a proximal location approximately 20 mm distal to the inguinal ligament during the frog-leg position.

Compared to other positions, such as the supine and Trendelenburg, the frog-leg position produced a greater increase in femoral vein CSA. This augmentation can be attributed to a reduction in external compressive forces exerted by surrounding musculoskeletal structures, as well as a positional shift that renders the femoral vein more superficial and accessible. Kim et al.¹⁷ previously demonstrated that

hip abduction combined with external rotation significantly diminishes extrinsic venous compression, resulting in a measurable increase in femoral vein CSA.

The highest CSA measurement in the present study was achieved in the combined reverse Trendelenburg and frog-leg position, where the mean CSA reached 1.51 ± 0.11 cm². Consistent with these results, Kim et al.¹⁷ reported a 77.2% increase in femoral vein CSA in the same combined posture, a magnitude considered clinically significant for improving first-attempt success rates in femoral venous catheterisation.

When evaluating sex-related differences, male participants demonstrated significantly higher CSA values in all positions compared to female participants. The larger femoral vein diameter observed in males can be attributed to their inherently greater skeletal muscle mass and increased venous return demands. This finding is consistent with previous studies in the literature, which have reported that males tend to have a wider femoral vein diameter than females.²⁰

Age was found to exert a significant influence on femoral vein CSA, with a positive correlation observed between advancing age and mean CSA values. This age-related increases in femoral vein calibre likely reflect diminished vascular wall elasticity and progressive luminal dilatation, driven by extracellular matrix remodeling such as elastin degradation and collagen deposition.²¹

Consequently, older individuals may experience a more pronounced augmentation in femoral vein CSA in response to positional modifications. Similarly, a positive association was identified between BMI and femoral vein CSA. Participants classified as obese (class I) demonstrated significantly higher CSA values compared to those in the underweight and underweight/normal-weight categories. Keiler et al.²⁰ found a strong positive correlation between BMI and femoral vein diameter in adults, confirming that increased BMI is linked to enlarged venous dimensions.

These results indicate that BMI constitutes a relevant anthropometric determinant of femoral vein dimensions and contributes to variations in venous haemodynamics within the lower extremities.

Limitations

This study was conducted at a single institution with a relatively limited sample size, which may constrain the external validity and generalisability of the findings to broader populations. Although all ultrasonographic measurements were performed by a radiologist with extensive clinical experience, the exclusive use of a single operator may have introduced measurement bias. It should also be noted that the radiologist was not blinded to the participants' body positions during imaging, potentially introducing observer bias into the data acquisition process.

CONCLUSION

This study presents clear evidence regarding the effects of various body positions on femoral vein CSA. These findings highlight the importance of selecting optimal patient positioning to potentially improve femoral venous access. While differences across positions were observed, the data suggest that demographic and anthropometric factors such as age, sex, and BMI have a substantial influence on femoral vein CSA. These results contribute to a better understanding of how both patient characteristics and positioning can affect vascular calibre and may assist clinicians in tailoring their approach to central venous access more effectively.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was carried out with the permission of Scientific Researches Evaluation and Ethics Committee of Ankara Etlik City Hospital No. 1. (Date: 30.04.2025, Decision No: 2025/157).

Informed Consent

All patients signed and free and informed consent form.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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